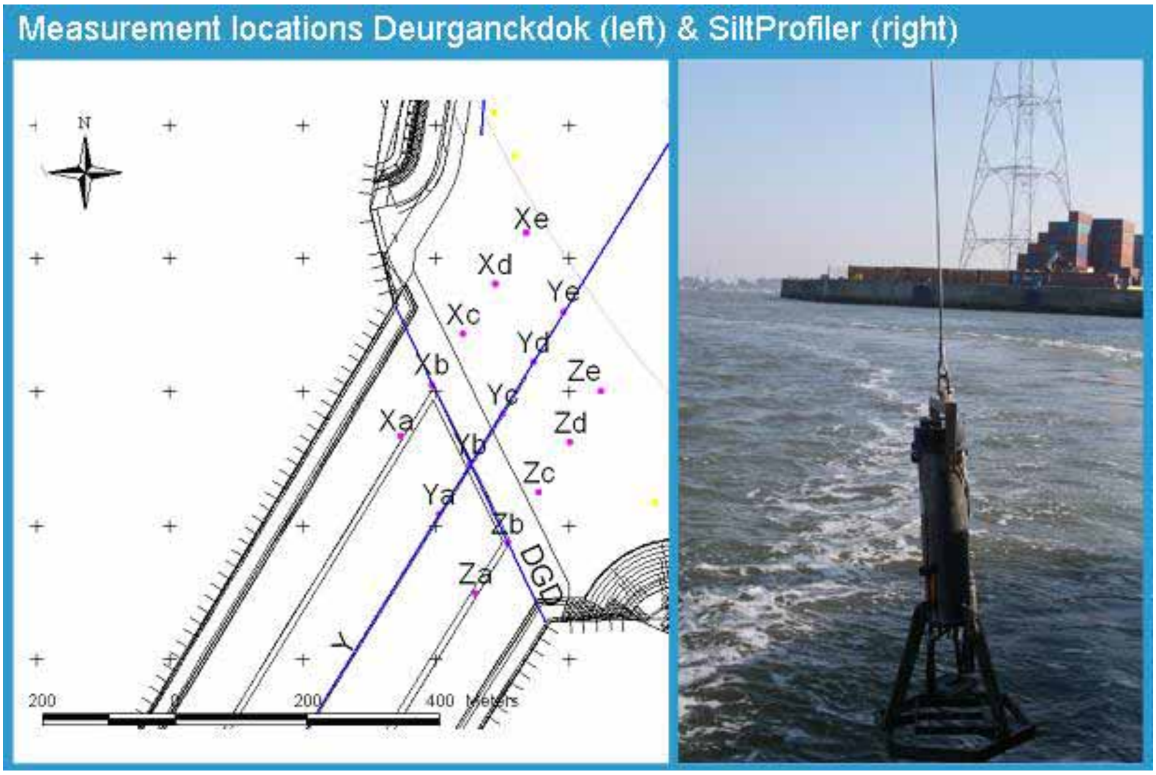
VLAAMSE OVERHEID
DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN

WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04



Deelrapport 2.30: 13u-meting SiltProfiler 13 Maart 2009 Ingang Deurganckdok

Report 2.30: Through Tide Measurement SiltProfiler 13 March 2009 at the entrance of Deurganckdok

4 September 2009

I/RA/11283/08.091/MSA

i.s.m.

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1. INTRODUCTION

1.1. The assignment

This report is part of the set of reports describing the results of the long-term measurements conducted in Deurganckdok aiming at the monitoring and analysis of silt accretion. This measurement campaign is an extension of the study “Extension of the study about density currents in the Beneden Zeeschelde” as part of the Long Term Vision for the Scheldt estuary. It is complementary to the study ‘Field measurements high-concentration benthic suspensions (HCBS 2)’.

The terms of reference for this study were prepared by the ‘Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Waterbouwkundig Laboratorium’ (16EB/05/04). The repetition of this study was awarded to International Marine and Dredging Consultants NV in association with WL|Delft Hydraulics and Gems International on 10/01/2006. The project term was prolonged with an extra year from April 2007 till March 2008 and a second time prolonged with one extra year from April 2008 till March 2009.

Waterbouwkundig Laboratorium– Cel Hydrometrie Schelde provided data on discharge, tide, salinity and turbidity along the river Scheldt and provided survey vessels for the long term and through tide measurements. Afdeling Maritieme Toegang provided maintenance dredging data. Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust and Port of Antwerp provided depth sounding measurements.

The execution of the study involves a twofold assignment:

- Part 1: Setting up a sediment balance of Deurganckdok covering a period of two years, i.e. 04/2007 – 03/2009
- Part 2: An analysis of the parameters contributing to siltation in Deurganckdok

1.2. Purpose of the study

The Lower Sea Scheldt (Beneden Zeeschelde) is the stretch of the Scheldt estuary between the Belgium-Dutch border and Rupelmonde, where the entrance channels to the Antwerp sea locks are located. The navigation channel has a sandy bed, whereas the shallower areas (intertidal areas, mud flats, salt marshes) consist of sandy clay or even pure mud sometimes. This part of the Scheldt is characterized by large horizontal salinity gradients and the presence of a turbidity maximum with depth-averaged concentrations ranging from 50 to 500 mg/l at grain sizes of 60 - 100 μm. The salinity gradients generate significant density currents between the river and the entrance channels to the locks, causing large siltation rates. It is to be expected that in the near future also the Deurganckdok will suffer from such large siltation rates, which may double the amount of dredging material to be dumped in the Lower Sea Scheldt.

Results from the study may be interpreted by comparison with results from the HCBS and HCBS2 studies covering the whole Lower Sea Scheldt. These studies included through-tide measurement campaigns in the vicinity of Deurganckdok and long term measurements of turbidity and salinity in and near Deurganckdok.

The first part of the study focuses on obtaining a sediment balance of Deurganckdok. Aside from natural sedimentation, the sediment balance is influenced by the maintenance and capital dredging works. This involves sediment influx from capital dredging works in the Deurganckdok, and internal relocation and removal of sediment by maintenance dredging works. To compute a sediment balance an inventory of bathymetric data (depth soundings), density measurements of the deposited material and detailed information of capital and maintenance dredging works will be made up.

The second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok, it is important to follow the evolution of the parameters involved, and this on a long and short term basis (long term & through-tide measurements). Previous research has shown the importance of water exchange at the entrance of Deurganckdok is essential for understanding sediment transport between the dock and the Scheldt river.

1.3. Overview of the study

1.3.1. Reports

Reports of the project ‘Opvolging aanslibbing Deurganckdok’ between April 2008 till March 2009 are summarized in Table 1-1. An overview of the HCBS2, ‘Opvolging aanslibbing Deurganckdok’ (between April 2006 till March 2007) and ‘Opvolging aanslibbing Deurganckdok’ (between April 2007 till March 2008) reports are given in APPENDIX J.

This report, report 2.30, is one of set of reports for understanding the sediment transport between Deurganckdok and the river Scheldt, which belongs to the second part of this project.

Table 1-1: Overview of Deurganckdok Reports between April 2008 till March 2009

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.20	Sediment Balance: Three monthly report 1/4/2008 - 30/6/2008 (I/RA/11283/08.076/MSA)
1.21	Sediment Balance: Three monthly report 1/7/2008 – 30/9/2008 (I/RA/11283/08.077/MSA)
1.22	Sediment Balance: Three monthly report 1/10/2008 – 31/12/2008 (I/RA/11283/08.078/MSA)
1.23	Sediment Balance: Three monthly report 1/1/2009 – 31/03/2009 (I/RA/11283/08.079/MSA)
1.24	Annual Sediment Balance (I/RA/11283/08.080/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations	
2.20	Through tide measurement Sediview DGD during average tide Spring 2008 – 19 June 2008 (I/RA/11283/08.081/MSA)
2.21	Through tide measurement Sediview DGD during average tide Spring 2008 –26 June 2008 (I/RA/11283/08.082/MSA)
2.22	Through tide measurement Sediview DGD during neap tide Summer 2008 – 24 September 2008 (I/RA/11283/08.083/MSA)
2.23	Through tide measurement Sediview DGD during spring tide Summer 2008 – 30 September 2008 (I/RA/11283/08.084/MSA)
2.24	Through tide measurement Sediview DGD during neap tide Autumn 2008 – 02 December 2008 (I/RA/11283/08.085/MSA)
2.25	Through tide measurement Sediview DGD during spring tide Autumn 2008 – 10 December 2008 (I/RA/11283/08.086/MSA)
2.26	Through tide measurement Sediview DGD during neap tide Winter 2009 – 06 March 2009 (I/RA/11283/08.087/MSA)
2.27	Through tide measurement Sediview DGD during spring tide Winter 2009 – 12

Report	Description
	March 2009 (I/RA/11283/08.088/MSA)
2.28	Through tide measurement ADCP eddy DGD Summer 2008 – 1 October 2008 (I/RA/11283/08.089/MSA)
2.29	Through tide measurement Siltprofiler DGD Summer 2008 – 29 September 2008 (I/RA/11283/08.090/MSA)
2.30	Through tide measurement Siltprofiler DGD Winter 2009 – 13 March 2009 (I/RA/11283/08.091/MSA)
2.31	Through tide measurement Salinity Profiling DGD Winter 2009 – 11 March 2009 (I/RA/11283/08.092/MSA)
2.32	Salt-Silt distribution Deurganckdok: Six monthly report 1/4/2008 - 30/9/2008 (I/RA/11283/08.093/MSA)
2.33	Salt-Silt distribution Deurganckdok: Six monthly report 1/10/2008 – 31/3/2009 (I/RA/11283/08.094/MSA)
2.34	Calibration stationary & mobile equipment Autumn 2008 – 27 & 28 October 2008 (I/RA/11283/08.095/MSA)
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.20	Boundary conditions: Six monthly report 1/4/2008 – 30/09/2008 (I/RA/11283/08.097/MSA)
3.21	Boundary conditions: Six monthly report 1/10/2008 – 31/03/2009 (I/RA/11283/08.097/MSA)
Analysis	
4.20	Analysis of Siltation Processes and Factors (I/RA/11283/08.098/MSA)

1.3.2. Measurement actions

Following measurements have been carried out during the course of this project:

1. Monitoring upstream discharge in the river Scheldt.
2. Monitoring Salt and sediment concentration in the Lower Sea Scheldt taken from on permanent data acquisition sites at Oosterweel, Prosperpolder and up- and downstream of the Deurganckdok.
3. Long term measurement of salt distribution in Deurganckdok.
4. Long term measurement of sediment concentration in Deurganckdok
5. Monitoring near-bed processes in the central trench in the dock, near the entrance as well as near the landward end: near-bed turbidity, near-bed current velocity and bed elevation variations are measured from a fixed frame placed on the dock's bed.
6. Measurement of current, salt and sediment transport at the entrance of Deurganckdok for which ADCP backscatter intensity over a full cross section are calibrated with the Sediview procedure and vertical sediment and salt profiles are recorded with the SiltProfiler equipment
7. Through tide measurements of vertical sediment concentration profiles -including near bed highly concentrated suspensions- with the SiltProfiler equipment. Executed over a grid of points near the entrance of Deurganckdok.

8. Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks
9. Monitoring dredging and dumping activities in the Lower Sea Scheldt

In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors (IMDC, 2006a, IMDC, 2007a, 2008f and 2009c).

1.4. Structure of the report

This report is the factual data report of the through tide measurements at Deurganckdok on the 13th of March , 2009. The first chapter comprises an introduction. The second chapter describes the measurement campaign and the equipment. Chapter 3 describes the course of the actual measurements. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

2. THE MEASUREMENT CAMPAIGN

2.1. Overview of the studied parameters

The first part of the study aims at determining a sediment balance of Deurganckdok and the net influx of sediment. The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging (Figure 2-1).

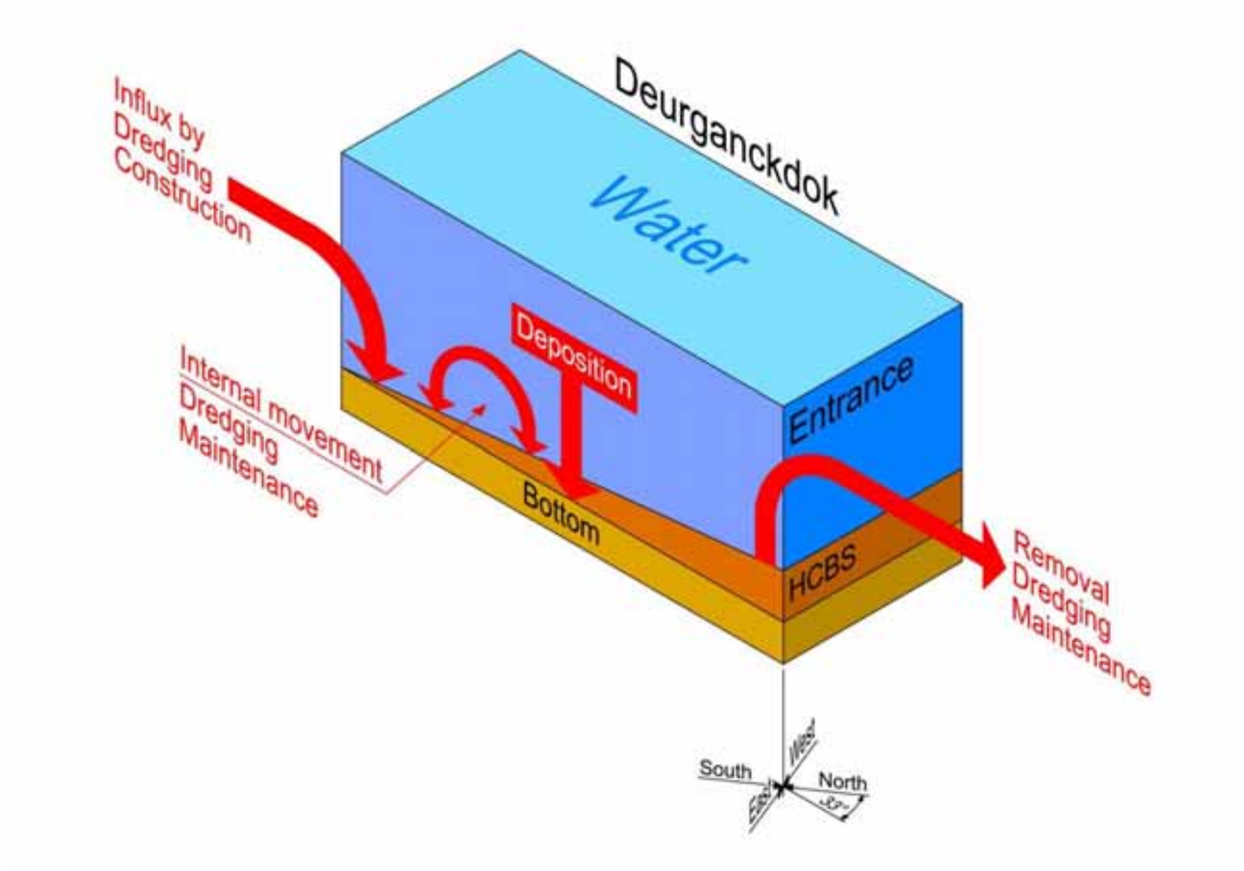

Figure 2-1: Elements of the sediment balance

A net deposition can be calculated from a comparison with a chosen initial condition t_0 (Figure 2-2). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t_0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t_0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the Scheldt river since t_0.

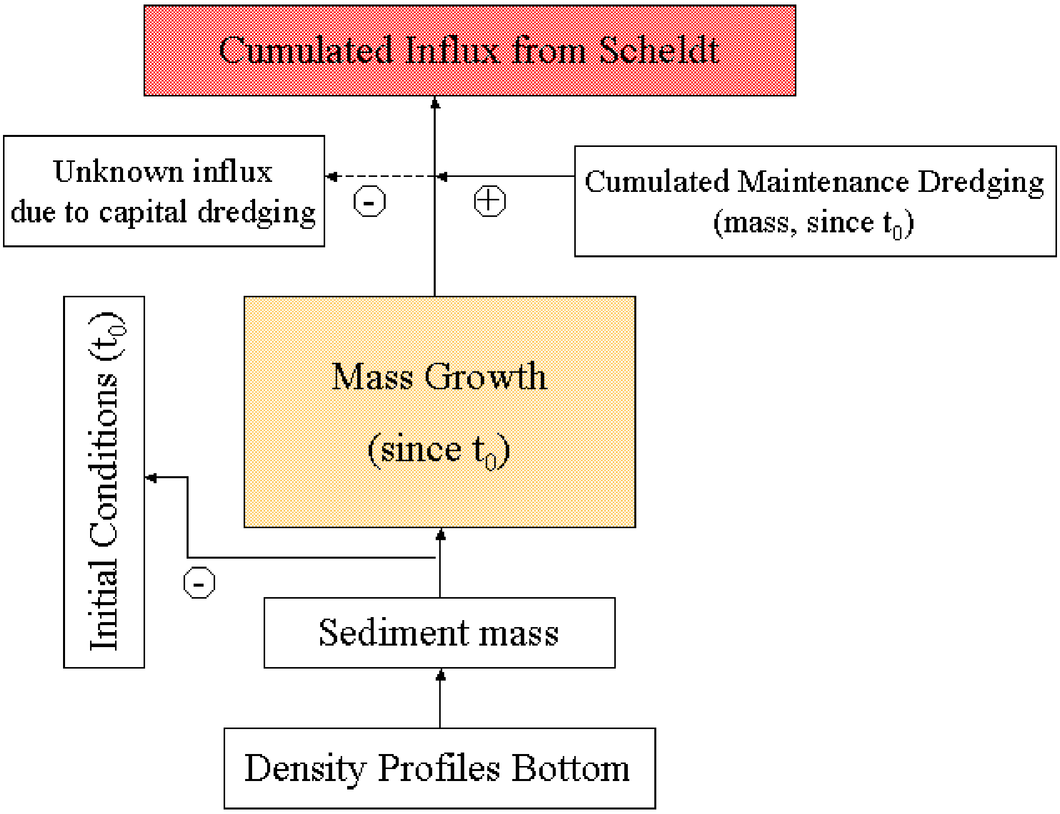

Figure 2-2: Determining a sediment balance

The main purpose of the second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok. The following mechanisms will be aimed at in this part of the study:

- Tidal prism, i.e. the extra volume in a water body due to high tide
- Vortex patterns due to passing tidal current
- Density currents due to salt gradient between the Scheldt river and the dock
- Density currents due to highly concentrated benthic suspensions

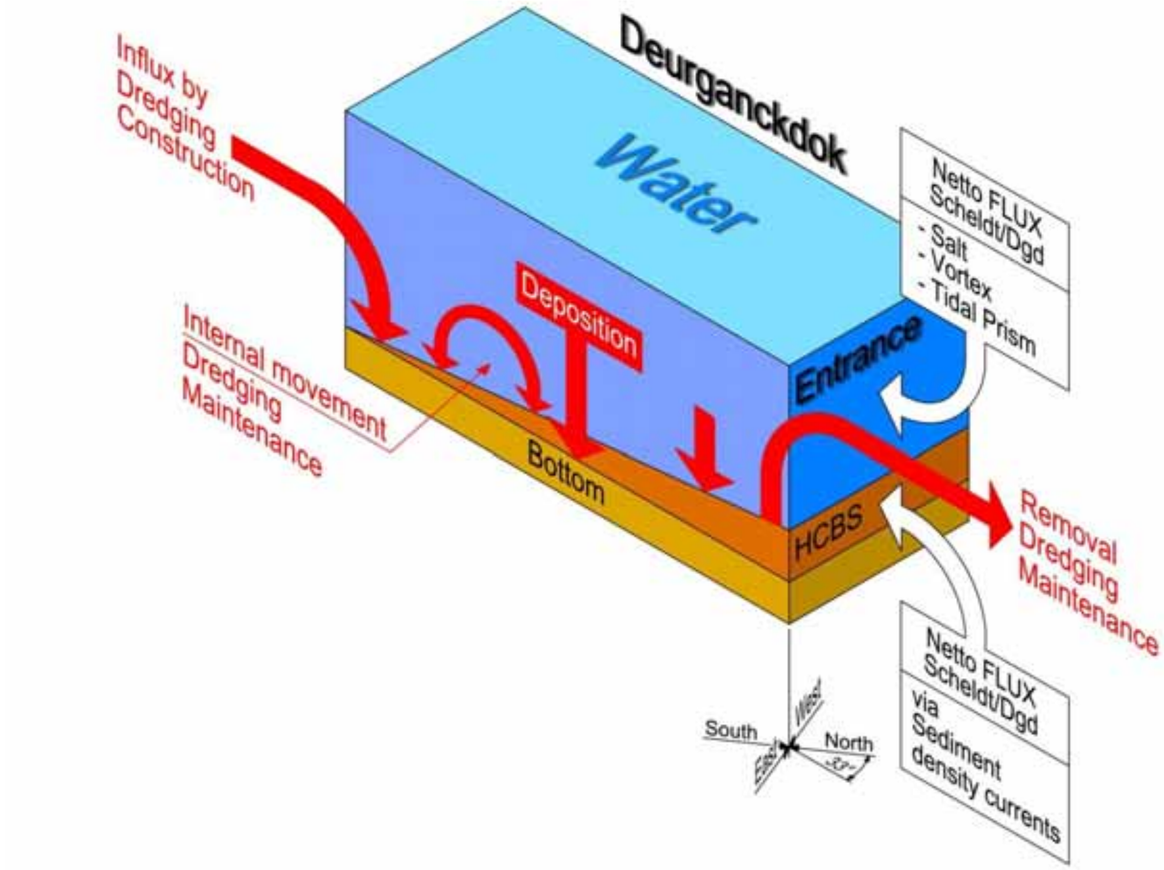

Figure 2-3: Transport mechanisms

These aspects of hydrodynamics and sediment transport have been landmark in determining the parameters to be measured during the project. Measurements will be focussed on three types of timescales: one tidal cycle, one neap-spring cycle and seasonal variation within one year.

Following data are being collected to understand these mechanisms:

- Monitoring upstream discharge in the Scheldt river.
- Monitoring Salt and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Lillo, Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurement of salt and suspended sediment distribution in Deurganckdok.
- Monitoring near-bed processes (current velocity, turbidity, and bed elevation variations) in the central trench in the dock, near the entrance as well as near the current deflecting wall location.
- Dynamic measurements of current, salt and sediment transport at the entrance of Deurganckdok.
- Through tide measurements of vertical sediment concentration profiles -including near bed high concentrated benthic suspensions.
- Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks as well as dredging and dumping activities in the Lower Sea Scheldt.

2.2. Description of the measurement campaign

Turbidity, salinity and temperature measurements were conducted on the March 13th of 2009 from 6h20 MET till 18h15 MET. The measurement campaign was stopped 1 hour earlier because of a technical problem.

The purpose of the measurements was to find fluid mud layers and to determine the distribution of suspended sediment over the dock's entrance area during a complete tidal cycle. For measurements in Deurganckdok the terms 'left bank' and 'right bank' will be used to address the North quay wall and South quay wall respectively.

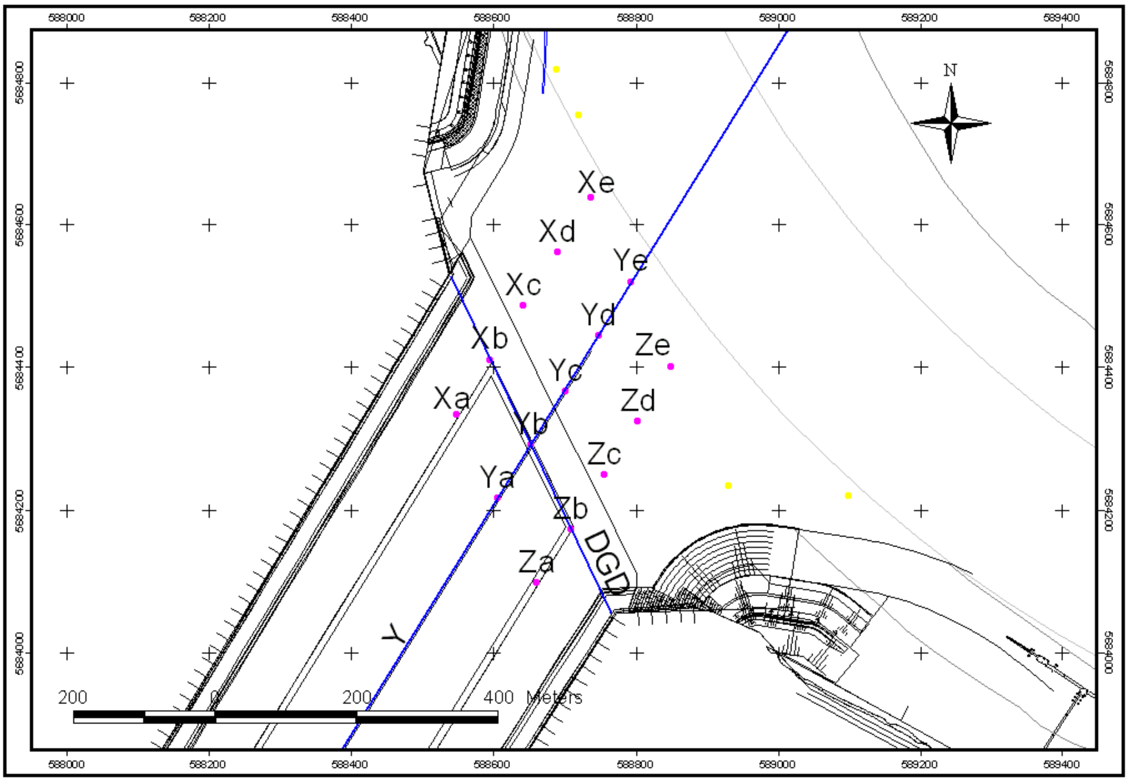

Figure 2-4: Map of the measurement locations in the vicinity of Deurganckdok

From the survey vessel Scheldewacht II a measurement cycle was completed sailing three parallel transects (X, Y and Z) at the entrance of the Deurganckdok (Figure 2-4). A high resolution turbidity profile was measured with the SiltProfiler at 5 locations on each transect.

An overview with all the measurement locations of the SiltProfiler measurements can be found in Table 2-1.

Table 2-1: Positions of the measurement points for March 13th 2009 at the entrance of Deurganckdok.

Measurement point	***Bank***	***Easting (UTM31 ED50)***	***Northing (UTM31 ED50)***	***Average Depth [m TAW]***
Xa	Left bank	588549	5684335	-15.0
Xb	Left bank	588596	5684411	-14.1
Xc	Left bank	588643	5684486	-13.3
Xd	Left bank	588690	5684562	-13.5
Xe	Left bank	588737	5684638	-14.0
Ya	Center	588606	5684217	-15.1
Yb	Center	588653	5684293	-14.3
Yc	Center	588700	5684368	-14.6
Yd	Center	588747	5684444	-14.5
Ye	Center	588793	5684520	-14.7
Za	Right bank	588662	5684099	-15.2
Zb	Right bank	588709	5684174	-13.8
Zc	Right bank	588756	5684250	-13.7
Zd	Right bank	588803	5684326	-14.1
Ze	Right bank	588850	5684402	-13.9

2.3. The equipment

2.3.1. SiltProfiler

The SiltProfiler has the following general specifications. The data collection is executed locally (i.e. on the profiler) by an integrated data logger. Sensor cables are kept very short and connect to the interfacing electronics of the data logger. The data logger collects the sensor signals and records the same in internal memory. Simultaneously the data are transmitted via a serial communication cable (if connected). Emphasis is on fast data collection and less on the absolute accuracy of the sensors.

In case the communication cable is not connected, the data can be retrieved upon recovery of the profiler via a short range wireless connection. As soon as the profiler breaks the water surface the data can be accessed and transferred to the operator's PC, whereupon the profiler is ready for a new profiling session. The retrieved profile data are visualised immediately in depth profile graphs. This operational mode requires no electrical cables to be attached to the profiler. However, a small box (diameter in the order of 20 cm) with electronics, data logger and batteries is attached to the profiler. The hoisting cable is attached to sturdy structure above the electronics box.

The sensors are:

- one Conductivity and Temperature sensor with measuring ranges adequate for use in seawater.
- multiple turbidity sensors to cover the entire range of 0 to 35 000 mg/L suspended solids: 2 transmittance sensors (type FOSLIM) are used, in combination with a Seapoint turbidity sensor (0-400 mg/l).
- one pressure sensor.

Figure 2-5: High Resolution SiltProfiler

As such the SiltProfiler is anticipated to rapidly profile the suspended sediment concentration as well as the salinity structure. The SiltProfiler can measure at variable speed up to 100 measurements per second (100 Hz).

The data collection rate is adjustable to optimize for the required vertical / temporal resolution. Further, the data acquisition rate will be depth dependent in such a way that the rate is low in the upper section of the profile and higher in de lower section. Both rates and the changeover depth are user adjustable. The duration of data retrieval depends upon the amount of collected data and the effective data transfer rate.

2.3.2. CTD-Diver

A CTD-Diver was used to measure depth, conductivity and temperature. This instrument was placed on the SiltProfiler as backup for the SiltProfiler. During the measurement campaign all sensors (temperature, pressure and conductivity) were set to record every second.

The technical details about the CTD-Diver are given in APPENDIX A.

3. COURSE OF THE MEASUREMENTS

3.1. Measurement periods

SiltProfiles were taken at all 15 locations. 269 profiles were successfully measured with the SiltProfiler.

3.2. Hydro-meteorological conditions during the measurement campaign

3.2.1. Vertical tide during the measurements

The vertical tide was measured at Liefkenshoek tidal gauge. Graphs of the tide at Liefkenshoek on the March 13th of 2009 can be found in APPENDIX C. Table 3-1 lists the most important characteristics (high and low tide) of the tide at those gauges on March 13th of 2009.

Table 3-1: High and Low Tide at Liefkenshoek Tidal Gauge on 13/03/2009

Liefkenshoek Tidal Gauge		
March 13th 2009		
	Time [MET]	*Water level [mTAW]*
HW (1)	04:40	6.00
LW (2)	11:50	-0.38
HW (3)	17:00	5.89
LW (4)	00:00*	-0.39

* LW on March 14th of 2009

In Table 3-2 the tidal characteristics of the tide on the 13th of March 2009 are compared to the average tide over the decade 1991-2000 (AMT, 2003).

Table 3-2: Comparison of the tidal characteristics of 13/03/2009 with the average tide, the average neap tide and the average spring tide over the decade 1991-2000 for Liefkenshoek.

	Neap tide (1991 - 2000)	***Avg Tide (1991 - 2000)***	***Spring Tide (1991 - 2000)***	***Tide 13/03/2009***
Water level [m TAW]				
HW (1)	4.63	5.19	5.63	6.00
LW (2)	0.39	0.05	-0.18	-0.38
HW (3)	-	-	-	5.89
LW (4)	-	-	-	-0.39
Tidal difference [m]				
Falling (1 to 2)	4.24	5.14	5.81	6.38
Rising (2 to 3)	4.24	5.14	5.81	6.27
Falling (3 to 4)	-	-	-	6.28
Duration [hh:mm]				
Falling (1 to 2)	6:40	6:50	7:02	7:10
Rising (2 to 3)	5:59	5:34	5:16	5:10
Falling (3 to 4)	-	-	-	7:00
Tide (1 to 3)	12:39	12:24	12:18	12:20
Tide (2 to 4)	-	-	-	12:10
Tidal coefficient				
Falling (1 to 2)	0.82	1.00	1.13	1.24
Rising (2 to 3)	0.82	1.00	1.13	1.22
Falling (3 to 4)	-	-	-	1.22

The tidal coefficients from 1.22 up to 1.24 for the measured tide of the March 13th of 2009 indicate that this tide has a larger tidal range than the average tide for the decade of 1991-2000, and can be classified as spring tide.

3.2.2. Meteorological data

Meteorological data at Woensdrecht (NL) was obtained from the website of the Dutch meteorological institute (KNMI) (KNMI, 2009).

The weather on the 13th of March 2009 was dry but cloudy in the evening and the wind blew from the southwest at an average velocity of 7 km/h with maximal gust velocity of 22 km/h. The air temperature varied between 2 and 12°C. The sky was visible with increasing clouds during the day. In the evening, the sky was overcast.

3.3. Navigation information

An overview of the navigation at the measurement location is given in APPENDIX D.

3.4. Remarks on data

A total of 269 profiles were successfully taken with the SiltProfiler, which are 18 cycles of 15 measuring points. Only 3 profiles contained corrupted data. Because of a technical problem, the measurement campaign was stopped 1 hour earlier at 18:15 MET. The first SiltProfile was taken at 6:20 MET.

4. PROCESSING OF DATASETS

4.1. Calibration of the turbidity sensors

A crucial aspect of the accuracy and reliability of the data concerns the calibration of the instruments before the measurement campaign. The calibration procedure is described in calibration report 2.34 (IMDC, 2009c).

4.2. Methodology of processing the SiltProfiler data

SiltProfiler data was validated and screened for outliers. Raw data were filtered.

Salinity was calculated using the temperature, conductivity and pressure in the pps-78 formula (Unesco, 1991 & IMDC, 2002)(see APPENDIX E). Turbidity values were converted to suspended sediment concentration.

The SiltProfiler contains 3 turbidity sensors. The Seapoint sensor is used for low concentrations (0-700 mg/l), the Long Range Extinction sensor covers the range between 400 mg/l – 5000 mg/l, after which the Short Range Extinction sensor (4000 mg/l – 35000 mg/l) takes over. All 3 sensors log simultaneously during a measurement. The switchover between two sensors in the processing is done as follows:

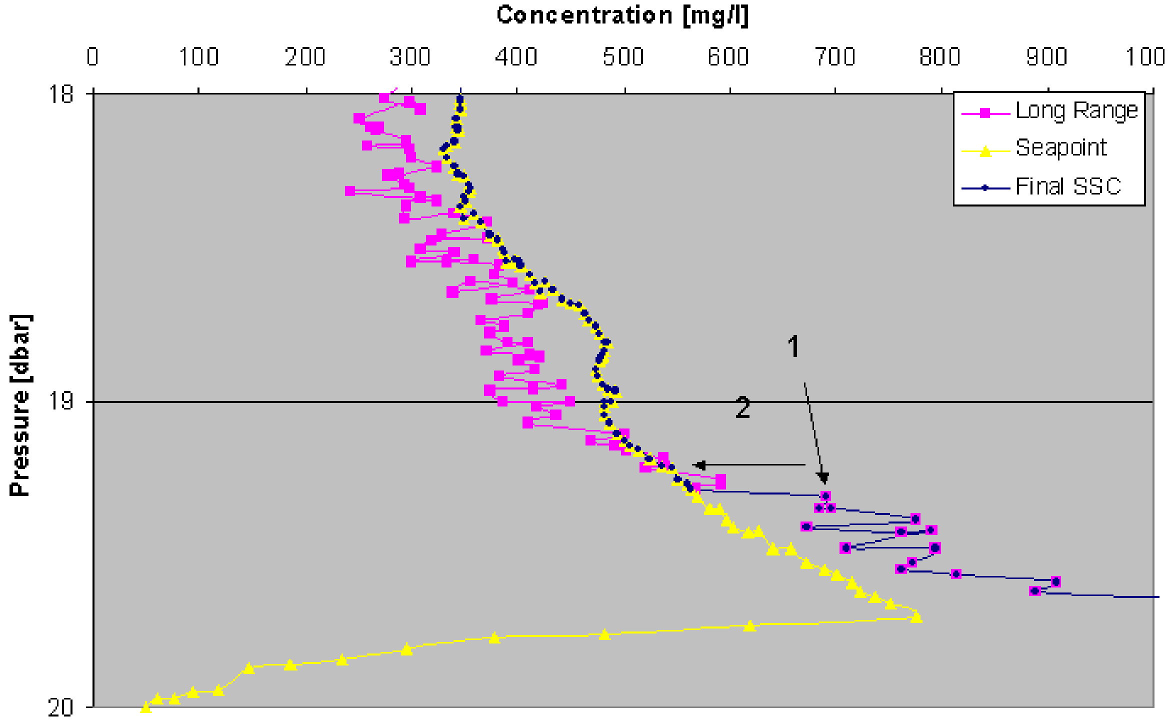

Figure 4-1: Example of Methodology used for the transition of Seapoint to Long Range Sensor for a given profile